

Precipitation was in excess in the Rocky Mountain and Plateau districts and thence over California and southern Oregon. In California the month was one of the wettest Marches on record.

Heavy rains in the second decade of the month caused exceptionally high stages in the Ohio River and tributaries. At Pittsburg, Pa., a stage of 35.5 feet was reached on the morning of the 15th. This is the highest stage of water ever recorded at Pittsburg, and exceeded the record stage of February 10, 1832, by 0.5 foot. The water at Pittsburg receded rapidly after the 15th, until the 19th, when another rainstorm caused a rise to 24.4 feet, 2.4 feet above the flood stage, at 5 p. m. on the 20th. Heavy rains that set in on the Pacific coast on the 16th and continued several days, combined with melting snow in the mountains, caused destructive floods in the Sacramento Valley, Cal.

The night of the 5th a heavy snowstorm, attended by high wind, thunder and lightning, visited the Middle Atlantic States. On the 10th a heavy snowstorm covered the Middle Atlantic and New England States and the Canadian Maritime Provinces.

BOSTON FORECAST DISTRICT.

Storms of notable severity occurred on the 11th, 19th, and 20th. On the 19th heavy snow fell in northern New England, and on the 20th the wind attained velocities on the coast of 35 to 77 miles an hour. Storm warnings were timely, and there was no damage and little delay to shipping.—*J. W. Smith, District Forecaster.*

NEW ORLEANS FORECAST DISTRICT.

Frost warnings were issued on two days and frost occurred in the section covered by the warnings. Frost occurred over limited areas, without warnings, on two days. Cold-wave warnings were not issued or required, and no general storm occurred on the Gulf coast.—*I. M. Cline, District Forecaster.*

LOUISVILLE FORECAST DISTRICT.

After the 13th exceptionally warm weather prevailed, and day after day March temperature records were broken. The month closed with a cold wave and killing frost, regarding which due warnings were issued. The flood in the Ohio River caused widespread damage, altho in this vicinity damage was not so great as from the January flood.—*F. J. Walz, District Forecaster.*

CHICAGO FORECAST DISTRICT.

The special features of the month were extremely high temperatures over practically the entire district, with no cold waves of consequence. Advisory messages were sent to open ports on Lake Michigan previous to the occurrence of storms, and no damage by storms is known to have occurred.—*H. J. Cox, Professor and District Forecaster.*

DENVER FORECAST DISTRICT.

March was wet west of the Continental Divide and dry on the eastern slope, with an excess of temperature thruout the district. In eastern Colorado the month was the mildest March on record. No cold-wave warnings were issued.—*F. H. Brandenburg, District Forecaster.*

SAN FRANCISCO FORECAST DISTRICT.

Unusually heavy precipitation caused destructive floods in central and northern portions of California. Storm warnings were necessary on a number of dates. There were some frosts, but fewer than usual.—*A. G. McAdie, Professor and District Forecaster.*

PORTLAND, OREG., FORECAST DISTRICT.

The month was not as stormy as usual. During a storm on the 22-23d maximum velocities of 74 miles at North Head, Wash., and 60 miles at Tatoosh Island were reported. No marine casualties were reported in connection with the storms of the month. Timely warnings were issued for all damaging frosts.—*E. A. Beals, District Forecaster.*

RIVERS AND FLOODS.

For the second time within the short period of two months the Ohio Valley was visited by a great flood. The flood waters from the great rise of January had scarcely past into the Mississippi before the rains that were to cause another began over the headwaters. The two floods differed materially in character in that above the mouth of the Great Kanawha River that of January was very moderate, while that of March was decidedly the reverse, so much so in fact that stages beyond all previous records were reached at Pittsburg and along the Youghiogheny River generally. The apparent antecedent conditions of the two floods were not greatly dissimilar, except that over the watershed of the Conemaugh and Kiskiminetas, the lower Youghiogheny, and the upper Allegheny rivers there were from 4 to 8 inches of moist, heavy, and comparatively fresh-fallen snow on the ground on March 10 and 11, whereas immediately preceding the flood of January there was little or none. The amount of rainfall was somewhat greater during the January flood, but in March differences in distribution, combined with high temperatures and the rapid melting of the snow over the Allegheny, Kiskiminetas, and Youghiogheny watersheds, caused a volume of water that more than compensated for the deficiency in the amount of precipitation.

The greater portion of the heavy rains fell on two successive days, the 13th and 14th, just at the time when, under the influence of temperatures that were from 10° to 25° above normal conditions, all the snows over the Allegheny and Monongahela watersheds were melting with great rapidity and running into the streams.

From the mouth of the Great Kanawha to the mouth of the Scioto the crest stages of the two floods were very nearly alike, as were also the periods of duration. Below the mouth of the Scioto the crest stages of March were from 1 to nearly 5.5 feet below those of January, on account of the limited supply of water contributed by the southern tributaries, notably the Great Kanawha, the Big Sandy, and the Guyandotte. This deficiency in the precipitation over the State of West Virginia is probably all that prevented a flood of much greater proportions. The headwaters of all northern tributaries were above flood stages, and had the West Virginia tributaries, with the Big Sandy, contributed their usual proportionate share of water, the flood of February, 1884, might easily have been compelled to yield its precedence, at least below the mouth of the Great Kanawha River.

The damage caused by the flood was approximately as follows:

Pittsburg, Pa.	\$5,600,000
Parkersburg, W. Va.	200,000
Cincinnati, Ohio.	200,000
Louisville, Ky.	100,000
Interior Ohio.	1,500,000
Total.	\$7,600,000

To these figures must be added the expense of moving property beyond reach of the flood waters, as well as the losses occasioned by the interruption of business, so that the total damage must have amounted to at least \$8,000,000.

An inspection of the weather maps and special reports shows that the flood at Pittsburg can be attributed mainly to the enormous volumes of flood waters caused by the excessive rains and melting snows from March 12 to 14 over the Kiskiminetas and Youghiogheny watersheds. The Monongahela, of course, contributed largely, but not so much as in the January flood, when the stages above the mouth of the Youghiogheny were from 3 to 5 feet higher. Not nearly so much rain fell over the upper Allegheny, less than 1 inch in fact, and no water of consequence came from the region above the mouth of the Kiskiminetas until the afternoon and evening of

March 14, when the breaking of the 6 or 8 feet of ice at Parker, Pa., released the backed-up water and augmented the flood volume of the lower river by about a foot or two. Preliminary warnings were issued on the morning of March 13 and special reports ordered from substations. By this time heavy rains and thunderstorms had interrupted the telegraph and telephone service so that it was impossible to obtain complete reports, and as a consequence the labor of issuing further flood warnings was attended with great difficulties. At 8 a. m. March 14 the stage of water at Pittsburg was 31.1 feet, having past the flood stage of 22 feet between 6 and 7 p. m. on the previous day. At the same time Johnstown, Pa., on the Conemaugh-Kiskiminetas reported 18 feet, 11 feet above flood stage, and the highest stage since the great flood of May 31, 1889. All previous records were exceeded on the Youghiogheny River, West Newton, Pa., reporting 26.3 feet, flood stage being 23 feet. The rise continued until 5 p. m., when a crest stage of 28.2 feet was reached, 6.2 feet above previous high records.

The river continued to rise at Pittsburg until 5 a. m., March 15, when a crest stage of 35.5 feet was reached, exceeding by 0.5 foot the previous high record of February 10, 1832, and by 2.2 feet the high-water mark of February 6, 1884. By 8 a. m., March 16, the river had fallen to 22.8 feet, and by 9 a. m. was once more below the flood stage.

In accordance with custom the municipal authorities of the cities of Pittsburg and Allegheny rendered extremely valuable assistance in the local dissemination of the flood warnings. Squads of police visited every house in the low-lying districts ordering the inhabitants to remove their property to places of safety, and all kept in close touch with the local Weather Bureau office.

About 4000 telephone calls were answered during the three days of the flood, and more than 1000 persons called at the office in search of information. The damage done in the immediate vicinity of Pittsburg amounted to about \$5,600,000, falling principally upon the manufacturing and electrical industries. As far as is known nine deaths in the Pittsburg district can be attributed to the flood, three by the collapse of a railroad bridge, and six by drowning in small streams. The damage to the river interests was practically nothing. Other losses above Pittsburg can not be satisfactorily estimated. On the morning of March 14 warning was also sent to Wheeling, W. Va., to expect a stage of 48 feet, 12 feet above the flood stage, by the afternoon of March 15, and again at 1 a. m., March 15, for a stage of 50 feet by midnight of the same date. The crest stage was 50.1 feet at 9 p. m. of the 15th.

This flood has resulted in the overturning of all precedents, and has established the fact that while the Allegheny is usually the prime factor in flood causation at Pittsburg it is not essentially so. In the present instance the bulk of the water undoubtedly came from the Youghiogheny, which was ably, but not so extensively, assisted by the Kiskiminetas and Monongahela. The Allegheny was quite sluggish, being backed up for many miles above Pittsburg, and contributed practically no water to the main flood volume until late in the afternoon of March 14, when the moving of the ice above permitted a little water to come thru.

The greatest previous flood at Pittsburg was that of February 10, 1832, when the water reached a stage of 35 feet, 0.5 foot below that of the present year. Mr. Henry Pennywitt, official in charge of the local office of the Weather Bureau at Pittsburg, has furnished the following extracts regarding this flood:

From the Pittsburg Gazette:

[Issue of February 10, 1832.] River in fine order, about 15 feet above low-water mark.

[Tuesday morning, February 14.] The winter commenced several weeks earlier than usual. On the 9th of January the ice broke up and navigation opened. On the 5th of February it began to rain, and continued to rain with slight interruptions until the night of the 9th. On

the 9th the rivers commenced to rise, and continued rising rapidly and regularly until 9 p. m. of Friday, the 10th, "when they were higher than had been known by any living inhabitant of this city or neighborhood". The whole of the low ground of the boroughs of the Northern Liberties and Allegheny and the greater part of the city of Pittsburg north of Liberty street were inundated. The damage in Pittsburg did not equal that in those boroughs. No estimate approaching accuracy can be made of the damage at this time.

[Tuesday, February 21.] The damage was less than at first estimated. At Pittsburg the crest was at 10 p. m., Friday, and at Wheeling, 8 p. m. Saturday.

From the History of Allegheny County:

The winter of 1831 set in early in November and the rivers were frozen until February, 1832, so that people were able to cross on the ice. There was some snow, enough for tolerably good sleighing, but not enough either in Pittsburg or on the mountains to give token of a large spring freshet. Albach, in his *Annals of the West*, says: "A winter of excessive cold was closed suddenly by long continued and very heavy rains, which, unable to penetrate the frozen ground, soon raised every stream emptying into the Ohio to an unusual height. The main trunk, unable to discharge the water which poured into it, overflowed its banks and laid the whole valley, in many places several miles in width, under water. The water continued to rise from the 7th to the 19th of February, when it attained a height of 63 feet above low-water mark at Cincinnati". Albach's statement of long continued and very heavy rains is not strictly correct. The rain which began to fall early in February, 1832, was a gentle, warm rain, not a very heavy one. It fell upon frozen ground, melting what little snow there was, and ran off as fast as it fell. The rains continued long enough to cause every tributary of the Ohio to overflow its banks. The rivers broke up on the 10th and had begun to fall on the 14th. Allegheny was covered with water to where the Fort Wayne road crosses Federal street. "The Point" at Pittsburg was from four to six feet under water, and the water extended to St. Clair street on Penn and Liberty. Wood street was overflowed as far as Fourth avenue. All communication between the town and the South Side was cut off.

Yet beyond the flooding of cellars and lower rooms, no special damage was done to Pittsburg. The people living near the rivers were inconvenienced for a time, and business was at a standstill for a few days, but a few weeks served to remedy all this inconvenience. The greatest material loss to Pittsburg was that of Smoky Island, which was carried away, together with a frame factory which it contained.

From the mouth of the Beaver River to Parkersburg, W. Va., the flood was remarkable for its unprecedented rate of rise, averaging 30 feet for the forty-eight hours ending at 8 a. m., March 15, and the stages were the highest of record, with the exception of those of February, 1884. In the Parkersburg district the stages were generally somewhat over 50 feet, Parkersburg reporting 51.6 feet, 15.6 feet above the flood stage, and Marietta, Ohio, 50.6 feet, 25.6 feet above the flood stage. Warnings were issued promptly, but in several instances they were not heeded as they should have been, some persons preferring to place more reliance upon previous experience than upon the actual knowledge in the possession of the Weather Bureau. As a consequence considerable damage was done that might have been avoided. The official warnings were characterized by extreme accuracy, and were the subject of much commendation.

Four lives were lost during the flood and the damage done amounted to about \$200,000.

From Parkersburg to Cairo conditions were very similar to those that prevailed during the flood of January, 1907, altho from Portsmouth, Ohio, southward, the crest stages were somewhat lower. The warnings were issued with the usual high degree of accuracy, and many letters of commendation were received. The damage done amounted to perhaps \$300,000 or \$400,000, considerably less than during the January flood.

A special hydrograph of the Ohio River, showing the stages from day to day, will be found on Chart IX.

The Wabash River was also in flood, with crest stages of 17.3 feet at Terre Haute, Ind., and 23 feet at Mount Carmel, Ill., on March 19 and 22, respectively, flood stages being at 16 and 15 feet. Warnings were issued from time to time and the crest stages differed from the forecast stage by only 0.4 foot.

While the flood was in progress along the upper Ohio, the interior rivers of the State of Ohio, without exception, were

also in flood, and an enormous amount of damage was done over the southern half of the State.

The following table contains the flood stages at the various stations, together with the crest stages of both the January and March floods, and the number of days the river was above the flood stage:

Station.	Flood stage.	Crest stages.		Days above flood stage.	
		January, 1907.	March, 1907.	January, 1907.	March, 1907.
Pittsburg, Pa.....	22	23.2	35.5	1	4
Wheeling, W. Va.....	36	36.9	50.1	2	4
Parkersburg, W. Va.....	36	40.1	51.6	6	6
Point Pleasant, W. Va.....	39	50.2	54.8	9	10
Huntington, W. Va.....	50	58.0	58.4	7	7
Catlettsburg, Ky.....	50	60.0	60.4	8	7
Portsmouth, Ohio.....	50	61.0	60.8	9	9
Maysville, Ky.....	50	60.3	59.2	9	9
Cincinnati, Ohio.....	50	65.2	62.1	11	12
Madison, Ind.....	46	56.7	51.9	10	10
Louisville, Ky.....	28	41.4	36.0	11	11
Evansville, Ind.....	35	46.2	44.8	30	17
Mount Vernon, Ind.....	35	48.5	45.0	31	16
Paducah, Ky.....	40	45.7	42.3	16	10
Cairo, Ill.....	45	50.4	46.2	16	9

At Hamilton the Great Miami River reached a stage of 20.3 feet, 8.3 feet above the flood stage, and within 0.9 foot of the highest water of record. From 3 to 9 a. m., on March 13, the river rose 10 feet.

Along the Scioto River conditions were still more pronounced. At Circleville the crest stage was 19.3 feet, 12.3 feet above the flood stage, the breaking of a levee alone preventing still higher stages. At Columbus the maximum stage was 19 feet, 2 feet above the flood stage. Similar conditions prevailed along the Muskingum River, and at Zanesville on March 14, the water reached a stage of 31.9 feet, 6.9 feet above the flood stage.

The Hocking River, altho quite small, really caused more damage than any other river in the State. The Hocking Valley Railroad suffered to the extent of \$170,000, the loss to the coal mines by flooding was about \$1,000,000, and a few small towns were nearly destroyed. Nothing serious occurred along the Sandusky and Maumee rivers, altho flood stages were general. The total damage in the State of Ohio caused by the floods, aside from that along the main river, amounted to at least \$1,500,000, and possibly more.

Warnings were issued from the local office of the Weather Bureau at Columbus, Ohio, on March 14 and 15 to all points likely to be affected by high water, and reports from flooded districts stated that they were the means of saving a great amount of property.

The crest of the Ohio River flood past into the Mississippi on March 24, and as it closely followed another rise moving slowly toward the Gulf, the two were in a measure merged into one long swell with a very leisurely movement. At the end of the month the river was above flood stage as far south as Arkansas City, and still rising slowly below. Advisory warnings were issued at the proper time in both the Memphis and Vicksburg districts. The only damage was caused by the overflow of some early seeded fields along the lower Yazoo River, but planting operations were generally delayed and levee work entirely suspended.

There were some heavy rains along the Cumberland and lower Tennessee rivers during the last day or two of February and the first two days of March, necessitating warnings of moderate floods which were well verified. No damage was done.

Flood waters caused by ice gorges did much damage along the Missouri River between Pierre, S. Dak., and Sioux City, Iowa, during February and early March, and the following report thereon was prepared by Mr. C. D. Reed, official in charge of the local office of the Weather Bureau at Sioux City, Iowa:

A warm spell from February 9 to 17, over the region between the Missouri River and the Rocky Mountains, caused all the tributaries flowing into the Missouri from the west and the headwaters of the Missouri itself to break up with more than the usual volume of water, the snow-fall in this region having been above normal. On February 15, the Bad River broke up suddenly at Fort Pierre, S. Dak., pushed large quantities of ice out over and under the solid ice in the Missouri, and flooded the lowlands on the Fort Pierre side, damaging barges and other property belonging to the U. S. Engineers, to the amount of \$3000. At about the same time, the White River broke suddenly and rose rapidly near Oacoma, S. Dak., causing a loss of live stock and farm buildings estimated at \$3000.

On Sunday, February 17, the Missouri began to break up from just above Sioux City to above Running Water, S. Dak. Altho above the normal February stage, the Missouri was yet 5 feet below flood stage at Sioux City and at Yankton. Without some stoppage in the movement of the ice, no flood damage could possibly have occurred, but during the forenoon of February 17, the ice began lodging on a sand bar in Gundersen's Bend, four miles southeast of Vermilion, S. Dak. In five hours the water rose 12 feet and began flowing over the bottom lands. By Monday morning the 18th the water had broken thru the Chicago, Milwaukee, and St. Paul Railroad grade between Vermilion and Burbank, and began flooding the land north of the track. It is reported that the current was so strong that huge cakes of ice were carried over the railroad and into the fields on the other side.

At 10 p. m. of the 17th, upon the meager and somewhat conflicting information that could be gathered from unofficial sources, warnings were issued to interests on lowlands in the vicinity of Sioux City, advising the removal of all live stock to higher ground at once and the preparation of movable property for transfer on short notice. On the following morning this warning was distributed at Jefferson, and Elk Point, S. Dak., and Jackson, Nebr.:

"Gorge in Missouri River threatens damaging flood. Every precaution should be taken on lower lands".

During the afternoon of the 18th, a portion of the gorge became detached and past down to Renniker's Neck opposite Jackson, Nebr., where it lodged, causing the water to overflow the banks. A new channel was soon cut and much of the ice remained stranded. During the afternoon of the 18th heavy ice began passing Sioux City and while not really forming a gorge, it clogged the channel just below the mouth of Big Sioux River, causing the water to back up that river so that it began to flow into the basements of some of the boat club houses at Riverside, and came within an inch of the grates under the boilers used in heating Elder's greenhouses. An estimated stage of 14 feet occurred at the Sioux City gage during the night of the 18-19th.

After the partial break in the gorge at Vermilion on the 18th it rapidly reformed, and during the next few days extended up the river past Vermilion a total distance of 10 or 12 miles. The ice in many places became piled up to a height of 10 to 15 feet above the water level, and a few huge cakes became tipped up on edge so that they stood 25 feet high. The water spread over a large territory on both sides of the river, but especially on the South Dakota side from below Burbank to above Meckling. It is estimated that 100 square miles of land not usually overflowed were inundated, and much of this was valuable farming land. Within about ten days the water cut channels around and thru the gorge and began to subside gradually. The breaking up of the Missouri at Pierre, S. Dak., on March 7, with a 3-foot rise, closed the outlets around the gorge to some extent, and a second rise occurred on the 9th and 10th of March, reaching about the same height as the previous rise and extending farther up the river, causing additional damage at Meckling and above.

At this time an effort was made by the U. S. Engineers to locate a point where the gorge could be effectively blasted away with gunpowder, but before a strategic point could be found, large sections from the lower end of the gorge began to break away and pass down the river at intervals. The main gorge began to move out at 3 p. m. of the 13th. As it past Vermilion the water rose 3 feet, remained stationary for a time, and then rose 4 feet more, due to a sudden stoppage of the gorge at some point below. The U. S. Engineers telephoned the local office of the Weather Bureau in Sioux City as to the breaking of the gorge and the total rise of 7 feet in six hours. On this information and because of the great probability of a sudden stoppage of the gorge at most any point below, it was deemed advisable to issue flood warnings for Jefferson and Elk Point, S. Dak., and Jackson and Walker's Island, Nebr., and interests in Sioux City affected by a stage of 17 feet. The warnings were all distributed before midnight of the 13th. An estimated stage of 14.5 feet occurred at Sioux City on the early morning of the 14th. As the ice moved out without stoppage, all danger of flood was soon past.

The flood in the vicinity of Vermilion continued twenty-four days, and was said by old residents to be the worst since March 25, 1881, when a gorge formed in a similar manner at about the same place. The total damage is estimated at \$100,000, of which probably \$20,000 might have been prevented if sufficient warning could have been given. On account of the caprices of ice gorges and the difficulty in securing reliable information from points between gage stations, the difficulty in accurately predicting such floods is obvious.

The flood in the Sacramento and San Joaquin valleys was doubtless the greatest in their history, and before the waters subsided damage amounting to at least \$5,000,000 had been done. An account of this flood has been prepared by Mr. James H. Scarr, official in charge of the local office of the Weather Bureau, Sacramento, Cal., and follows herewith:

Preliminary to a report on the great flood of the latter half of March, 1907, in the Sacramento and lower San Joaquin valleys, a glance at the rainfall tables of the climatological reports of the California section will serve to show a period of heavy and long-sustained precipitation extending from the 2d to the 17th of January. Then followed a nearly rainless period of a week, followed by another period of heavy precipitation, extending from January 24 to February 4. During these periods the rainfall was unusually heavy over the Sacramento watershed, gradually diminishing toward the south with heavy and accumulating snows in the higher Sierras.

These periods of heavy precipitation are mentioned because of their effect on the later flood situation in the Sacramento watershed. Conditions in the San Joaquin were not materially affected by these rains.

The precipitation of the first period mentioned produced the ordinary winter stages in the rivers of the Sacramento watershed, and the great overflow areas or storage basins known as Sutter, American, and Yolo basins began to fill.

The precipitation of the second period, ending about February 4, produced flood stages in all the streams of the Sacramento watershed, tho no new high-water records were made, except at Marysville, where the Yuba recorded a stage of 22.2 feet on February 2, 21.8 feet being the previous record.

On February 2 the American River at Folsom reached a stage of 21.2 feet, the highest known for many years. All local interests were warned by telephone. Two new railroad bridges in process of construction across the American River at this city were in great danger, but the companies' officials were warned in time to take all possible precautions, and as a result most of the structures were saved. By courtesy of the Capital and Pacific States Telephone companies all down-river points were warned of a rapid rise and advised to patrol all levees. Advisory warnings were sent to all points on the Sacramento from Colusa to Rio Vista daily as the situation seemed to warrant, and all local transportation interests were kept fully advised.

This flood wave in the upper Sacramento crested at Kennett on February 4 at 18.5, at Red Bluff on the 4th at 24.4, at Colusa on the 6th at 28.2, and at Knights Landing on the 6th at 18.8 feet. Below the latter place most of the flood waters of both the Sacramento and the Feather escape into the Yolo basin, returning to the Sacramento at Rio Vista thru Cache slough. At this city the Sacramento River continued to rise till the evening of the 8th, when at a stage of 26.9 feet the levee on the west side of the river opposite Y street (the south boundary of the city) broke, flooding a small district in Yolo County containing some 900 acres. The Southern Pacific Railroad grade cuts off the upper or northern end of this district, passing thru the village of Washington. A small portion of the town lying south of the railroad was flooded. The back levees of the district were cut to save the railroad grade, and the water quickly found its way to the Yolo basin on the west. With the occurrence of this break the river here began to decline steadily.

On the 7th the first of the flood wave was noticed in a one-foot rise at Rio Vista. A warning was sent that flood stages would probably be reached by the 12th. The river reached its highest stage of 13.3 feet at Rio Vista about noon of the 11th.

This flood did very little damage, but is interesting in this connection because it left the great storage basins full. The warnings issued were generally appreciated and eagerly sought by those whose interests are menaced by flood stages.

The lower San Joaquin River reached a fairly high stage, 15.8 feet, on the 9th, but as this is not dangerously high no warnings were sent. The daily river bulletin reaches Stockton at noon, and is ample to advise of stages in that watershed except in case of great emergency.

The rest of February was generally deficient in precipitation. The rivers declined to the usual winter stage and remained about stationary, responding slightly to a short precipitation period from the 21st to the 25th.

March shows two distinct precipitation periods—the first from the 2d to the 11th, only moderately heavy, but depositing fresh snow on the high mountains and well down on the foothills; the second extending from the 16th to the 25th and being very heavy. From the 16th to the 20th, inclusive, this rainfall over the northern half of the State, and especially in the watersheds of the upper Sacramento, Feather, Yuba, Bear, American, Mokelumne, Calaveras, Stanislaus, and Tuolumne rivers and over the watersheds of Stony, Cache, and Putah creeks, on the west side of the Sacramento Valley, was accompanied by unusually warm weather, especially at the higher altitudes, causing rapid melting of the soft snow and a run-off probably the heaviest since these valleys have been inhabited by civilized people. The average precipitation of four stations on the upper Sacramento for these five days is 8.90; for nine stations in the watershed discharging thru the Feather River 16.56; for six

stations in the American watershed 14.41; and for four stations along the eastern slope of the San Joaquin watershed 6.99 inches.

Individual stations reporting the greatest precipitation were Stirling City, 24.22 inches during this period, and 43.38 for the entire month; and Laporte 22.45 inches during this period, and 42.62 for the entire month.

The effect of this rainfall was immediate and extreme in all rivers affected. At Kennett, on the upper Sacramento, the river rose from 6.3 on the 17th to 20.0, 25.0, and 33.2 feet on the succeeding days; while in the Feather, Yuba, American, Mokelumne, Calaveras, Stanislaus, and Tuolumne, the climax was reached one day earlier.

On Sunday, the 17th, reports from Electra, Melones, and Jacksonville of stages of 8.0, 10.3, and 10.6 feet, respectively, warranted a warning advising of a sudden and extreme rise in tributaries of the San Joaquin and subsequent high stages in the main river. An advisory warning was also sent to Colusa on the strength of special report of heavy rainfall at Kennett, and all local interests were warned by telephone of a sudden and extreme rise in the American River.

On Monday, the 18th, conditions were rapidly growing worse in all sections of both watersheds. Special reports were called for from stations in the San Joaquin watershed and warnings were repeated to Stockton, to be distributed by special arrangements from that point. Advisory warnings were sent to Colusa and Marysville, and all local interests advised thru the courtesy of the telephone companies.

On Tuesday, the 19th, telegraph wires were down in many places, but on the showing of reports received in a regular way, and reports of rainfall by courtesy of the Southern Pacific Company, warnings were sent to Colusa to expect the highest water of record at all points from Kennett to Knights Landing. Warnings were sent to Stockton for highest water of record in the Tuolumne, Stanislaus, Calaveras, and Mokelumne rivers also that the lower San Joaquin and entire island district would experience the highest water of record after the 21st. The American River at Folsom crested at 26.8 feet this morning. It was learned later that the Yuba at Colgate crested at midnight on the 18th at 23.0 feet, 8.4 feet above the previous high-water stage of February 22, 1904. The Feather at Oroville crested on the morning of the 19th at 28.2 feet, 3.2 feet above the previous high-water stage of February, 1881. The Yuba at Marysville also crested on the morning of the 19th at 23.3 feet, 1.1 feet above the high-water record of February 2, 1907; the Mokelumne River at Electra at 13.0 feet, 4.0 feet above the previous highest known stage; the Calaveras at Jenny Lind at 13.0 feet, 3.0 feet above previous high water, and the Tuolumne at Jacksonville at 26.0 feet, by several feet the highest of record. The Stanislaus at Melones also reached a stage of 11.0 feet on the 19th, being above all previous records, tho it crested at 12.2 feet on the 21st.

On the afternoon of the 10th water from the Calaveras River overflowed the greater portion of the city of Stockton. The flood reached its greatest height about midnight, and in two or three days the water was gone from the streets. No lives were lost. The damage is estimated at half a million dollars, one half that sum being charged to goods in basements and lower floors damaged by wetting.

On Wednesday the 20th, the river at Kennett reached the remarkably high stage of 33.0 feet, 8.0 feet above any previously known stage, and began falling rapidly. At Red Bluff the flood wave crested at 27.5 feet at 4 p. m., 2.0 feet below the highest record stage of February 4, 1881. Colusa reported a stage of 28.6 feet, but 0.1 foot below the high-water stage of April 1, 1906, and with a certainty of a continued rise for twenty-four hours, unless relieved by breaking and overtopping levees. A special message at 4 p. m. announced a stage of 29.3 feet, with water running over the levees both above and below the city. Levees were also overtopped for nearly the whole distance from Princeton to Jacinto. At 8 p. m. another special message announced the inevitable breaking of the levees below Colusa, affording at least temporary relief to the levees in front of the city. All reports from the Feather River watershed showed declining stages. The American at Folsom declined 6 feet, but was still at an unusually high stage. The Sacramento at this place reached 26.9 feet, and began to decline. The slope of the water surface from the mouth of the American to the Kripp break, a distance of nearly 3 miles, was about 2 feet to the mile, and the current velocity was estimated by engineers and river men to be at least 12 miles an hour. It was evident that no flood stage could occur here under the conditions existing, but warnings to points on the river between here and Rio Vista were emphasized. The doubled current velocity here was forcing a much larger volume of water past the Kripp break than would have past that point at much higher stages at normal velocity. The break was also acting to reduce the slope of the flood plane below, and a consequent "piling up" of the water below was resulting not only in higher stages than would be indicated by the stage at Sacramento, but higher stages by several feet than were ever before recorded.

The river at Rio Vista began to respond to the flood waters on this date in a rise of 1 foot to a stage of 9.8 feet at 7 a. m., and warnings were issued that the river at that point would continue to rise till after Sunday and would pass all previous high-water records.

The San Joaquin crested at the bridge near Lathrop at 19.2 feet, 0.5 foot above the high-water mark of March 25, 1906. Long distance telephone calls were had from Stockton and other down-river points, and warnings and advices were distributed by this means. The Mokelumne

River near Woodbridge was reported to have broken its levees, and a large area was being flooded.

On Thursday the 21st, Kennett reported a decline of over 12 feet. Breaks had occurred near Princeton, and several breaks in Sutter County had flooded Reclamation District No. 70, resulting in the loss of considerable stock. Telephone lines were down and it was impossible to reach the district with the later warnings. Eleven breaks had occurred on the west side between Colusa and Grimes, and the river at Colusa was falling. At Knights Landing the river crested on this date at 20.2 feet, 1 foot above the previous high-water record. Breaks occurred in the levees above and below the town, flooding the greater part with back water. No lives were lost and not a great amount of damage was done in the town. The Feather, Yuba, and American rivers were falling. The Sacramento was falling at this city, but rising at all points below, including Riovista, where the returning flood waters from Yolo basin thru Cache slough caused a rise to a stage of 13.2 feet. All rivers in the San Joaquin watershed were falling except the San Joaquin at Firebaugh, the fall to a stage of 18.6 feet at the bridge near Lathrop being due to several breaks in the levees both above and below that point. Long distance telephone calls from Stockton, Elk Grove, Riovista, Walnut Grove, Isleton, and Courtland furnished means of repeated warnings that the rivers and sloughs of the island districts would continue to rise for several days, and would remain at dangerously high stages until after the 29th. San Francisco was asked for a special wind forecast at 4 p. m., and the following was received: "High southwest winds will prevail in the valley and Bay districts to-night and Friday morning". This warning was telephoned or telegraphed to all points that could be reached; under prevailing conditions it was deemed of the utmost importance, as wave action under strong wind pressure is apt to prove most destructive to nearly submerged levees. During the night several breaks occurred between Courtland and Walnut Grove on the east side of the Sacramento. This water past down on the back side of the Pierson district, adding to the already disastrous overflow from the Mokelumne, and threatening all reclamations in the lower San Joaquin delta.

On Friday, the 22d, most interest centered on the island districts, where the water continued to rise steadily. Riovista reported 15.5 feet, 0.5 foot above the high-water mark of March 23, 1904. The situation was growing desperate, but the only reply that could be given to the repeated telephone calls from the doomed reclamations was: "The worst is yet to come. Do not be deceived by a temporary decline on the ebbing tide. The water will rise steadily in most sections till after Sunday, and the danger will not be past for a week". Several districts in the San Joaquin delta, embracing more than 20,000 acres, were flooded. District No. 108, embracing 75,000 acres, mostly in Colusa County, gave way and began to fill rapidly.

Saturday, the 23d, was a most disastrous day. Ryer, Tyler, Brannan, Andrus, and Bouldin islands and the Lisbon district, embracing some 60,000 acres, all in the highest state of intensive cultivation, were flooded. This wholesale inundation, with the outgoing tide, caused a slight decline at all points on the Sacramento side, but warnings were repeated that a still further rise would occur at all points in the island district. On Sunday, the 24th, the river at Riovista reached its highest point, 18 feet, 3 feet above the previous high-water record, and began to decline. This decline was doubtless due to the breaking of the levees on Brannan, Andrus, and Twitchell islands. The water from the Yolo basin thru Cache slough was given a direct and free outlet to the San Joaquin instead of being confined to the narrow and crooked channel between Sherman Island and the Solano County hills. On this date the rich Pierson district, some distance below this city, which escaped the flood of 1904, and which by tremendous effort had so far been held, gave way, and 10,000 more acres of the most productive land in the world was given to the flood. Probably the largest loss of livestock occurred in this district, its value being estimated at \$60,000. This was not because of the lack of warning, but because the officers of the reclamation district were too confident of holding the district against all odds.

The breaking of Brannan, Andrus, and Twitchell islands now gave the waters from the Yolo basin, which were several feet higher than ever before known, a free sweep in an almost direct line from the outlet at Cache slough into the San Joaquin more than 75 miles above its mouth. The escaping water from the Sacramento in the vicinity of Courtland also found a direct outlet into the San Joaquin still higher up. As a result the water in the San Joaquin and sloughs below Stockton continued to rise in some sections till the 29th, tho at Lathrop the highest was reached on the 20th. In this section probably 40,000 acres were flooded after the 24th, the last tract of 2000 acres being submerged on the 29th.

To summarize, undoubtedly the flood of March 18 to 29, 1907, was the greatest since the lowlands of the Sacramento and San Joaquin valleys have been reclaimed to any considerable extent. It is probable that the volume of water discharged was equal to if not greater than that of 1862, referred to as the "great flood".

Nearly 300,000 acres of reclaimed land was flooded. The damage, including the loss of crops, which is far in excess of all other losses combined, will probably reach \$5,000,000. This does not include damage to railroads which was considerable. Very few lives were lost, and none

can be charged directly to the flood, so far as present advices indicate.

All previous high-water records were surpassed at all points reporting on the Feather, Yuba, and Bear rivers, also at all points on the Sacramento River, except Red Bluff and Sacramento. The Mokelumne, Calaveras, Stanislaus, and Tuolumne rivers past all previous records, as did also the San Joaquin below the mouth of the Tuolumne.

In judging of the service performed by the Weather Bureau in this emergency, it is hoped that it will be born in mind that this service embraces two entire river systems, each complicated and with sources of flood waters from numerous short, torrential streams. The situation in the most important part, viz, the island districts, is still further complicated by the union of the two systems at tide level by an intricate network of sloughs and channels, and the return to the main rivers by shorter routes of the escaped flood waters from above. Then again the service is comparatively new as regards administration, data secured, and the people and interests to be served.

The papers usually gave credit for the information furnished and repeated the warnings given, and the editors and reporters have personally expressed great appreciation of the service. Locally the State Board of Public Works, the transportation companies, and many owners of reclaimed lands have also expressed appreciation of the service rendered.

Our observer at Colusa writes:

"All farmers in flooded sections had received warnings from the Weather Bureau, and had ample time to remove stock to places of safety. No stock lost in Colusa County. * * * A copy of all warnings furnished to the press and posted on Market street and on Fifth street, and all farmers accessible by telephone notified. The service furnished by the Weather Bureau very satisfactory and greatly appreciated by all interests".

M. D. Eaton, of Stockton, to whom was sent the first warning on March 17, writing on the 18th, says:

"* * * I immediately telephoned, upon the receiving of your telegram, to different parties interested in reclaimed lands which might be affected by the possible extreme flood waters of the San Joaquin. It would be useless for me to say that we appreciate your action beyond any explanation. * * * Your telegram of yesterday created quite a stir among us and has given us an opportunity to prepare for dangerous waters".

J. M. Eddy, Secretary of the Stockton Chamber of Commerce, writes under date of April 4:

"In behalf of this Chamber of Commerce and the vested interests of this community, I wish to thank you for your successful efforts to keep this organization and our people apprised of the river stages and weather conditions during the recent floods, and to assure you that there is a very high appreciation of your work among those best informed and most concerned. I trust that the memory of this will influence our citizens to a greater degree of helpfulness to you in making your inquiries in the future".

In addition to the service rendered, the complete and unbroken record of river stages secured by this service during the flood will prove invaluable to all lines of hydrographic, reclamation, irrigation, and river improvement work.

The breaking up and downstream passage of the ice in both branches of the Susquehanna River resulted in some moderately high stages of water, but no damage of great consequence. At Binghamton, N. Y., the ice went out at 11 p. m. on March 15; at Towanda, Pa., at 10:30 a. m. of the same day, and at Wilkes-Barre, Pa., at 5 a. m., March 16, moving out on 16 feet of water.

At Clearfield, Pa., on the West Branch, the ice began to move at 6 p. m., March 13, and by 5 p. m. of the following day the water had reached a stage of 11.9 feet, 3.9 feet above flood stage. Several factories were compelled to suspend work for a few days, and some streets were washed out.

At Renovo, Pa., the ice went out at 7 a. m. on March 14, and at Williamsport, Pa., at 6 a. m. of the following day. In the main river the ice began to run on March 14.

The greatest damage was done at Port Deposit, Md., a large portion of which was flooded.

The dead body of a boy, found in the ice at Port Deposit, was afterward identified as that of one who had fallen into the North Branch from the Berwick Bridge, more than 150 miles above, on January 16, 1907.

Warnings of the stages of water to be expected were issued from Harrisburg, Pa., on March 13 and 14, and were of great benefit to those interested.

Considering the condition of the rivers, the manner of the ice breakup was most fortunate; first came the ice from the main river and the Juniata, then that from the West Branch,

followed a day later by that from the East Branch. Had all or any two come out together, a serious flood in the lower river would surely have resulted.

The rains of the latter days of February and March 1 caused a moderate flood in the Alabama River, and others somewhat more pronounced in the Black Warrior, the lower Tombigbee, and the rivers of southeastern Mississippi. Warnings were issued for all, and no damage worthy of special mention was done. On some of the rivers the floods were of benefit, as they permitted the movement of lumber that had been held for sufficient water to float it to market.

The heavy rains on March 13 and 14 caused severe and dangerous floods along the upper Potomac River and its headwaters, resulting in damage to the amount of about \$1,000,000, mainly to railroad interests. There was no damage of consequence below Cumberland, Md.

High water did some damage along the rivers of Idaho, the result of heavy rains and melting snows.

At the end of the month the Mississippi River was free from ice, which broke up at Leclaire, Iowa, on March 1, and at Fort Ripley, Minn., on March 27.

The rivers of Maine remained frozen, but the ice of the upper Connecticut gave way between March 27 and 29.

The highest and lowest water, mean stage, and monthly range at 312 river stations are given in Table VI. Hydrographs for typical points on seven principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.—*H. C. Frankenfield, Professor of Meteorology.*

SPECIAL ARTICLES, NOTES, AND EXTRACTS.

RAINFALL AND RUN-OFF OF THE CATSKILL MOUNTAIN REGION.¹

By THADDEUS MERRIMAN, Assistant Engineer. Dated Browns Station, N. Y., June 14, 1906.

The purpose of the studies on the rainfall and run-off of the Catskill watersheds, the results of which are embodied in this report, has been:

1. To determine the most probable mean annual rainfall on each of the four watersheds proposed to be used as an additional supply for the city of New York.
2. To determine the relation between the values of the rainfall on these watersheds and the values of the rainfall at other points where long and careful records have been kept.
3. To determine as closely as possible the percentage of the rainfall on these watersheds which may be expected to appear as streamflow and become available for the supply of the city.

RAINFALL.

An examination of rainfall records in the State of New York, particularly in the territory covered by the Rondout, Esopus, Schoharie, and Catskill watersheds, at once showed that practically no observations had ever been made in this immediate vicinity. There was found but one record within the limits of these watersheds, and that for a short period only. A number of records had been kept at distances varying from 3 to 20 miles, and located geographically around the area under consideration. An admirable digest of these records in the vicinity was made in the report of the Commission on Additional Water Supply for the city of New York, in 1903. This commission also established a number of gages on these watersheds. Observations were continued for about nine months, when the completion of the work of the commission caused their abandonment.

Ten rain gages have been established by the present Board of Water Supply, and these, in connection with the gages of the voluntary observers of the United States Weather Bureau, cover in excellent form all the territory of the four watersheds. For the future, therefore, the rainfall will be determined with a high degree of precision.

In order to fix the most probable mean value of the rainfall in this territory it was decided to make the study as comprehensive as possible. To this end, therefore, nearly all reliable records for points within approximately one hundred miles of the Ashokan basin which could be found in public documents were gotten out and studied. This work involved an examination of the records at 76 different stations, the records at all of the stations covering a total length of 1085 years.

The records studied were obtained from the following sources: (a) New York State Meteorology. (b) The New York

State Weather Bureau Reports. (c) The United States Weather Bureau Reports. (d) Records at miscellaneous points, as given in the report of the Commission on Additional Water Supply.

In the New York State Meteorology are assembled the records of observations made at the incorporated academies of the State, under the direction of the regents of the University of the State of New York. These records were begun in 1825 and carried on more or less continuously until the Civil War diverted attention from them, and they were forgotten.

Two different forms of gages were employed by these old-time observers. Prior to 1833 a gage with but little protection against evaporation was used. A conical mouthpiece collected the rain and delivered it into a cylinder the area of which was one-eighth that of the mouth of the collecting cone. In this cylinder there was a float connected to a graduated scale which projected above the top of the gage, and on which the depths were read. In cold weather a vessel having the same area of mouth as the collector of the gage was set out. The snow was caught in this vessel, melted, and measured in the gage. This vessel was not more than 6 inches deep, and it is doubtful if the precipitation during the winter months, as determined by this device, was even of a reasonable degree of accuracy. In fact, an inspection of these records shows that the rainfall during the winter season was then apparently quite uniformly lower than that which is recorded by gages at the present time; there is no reason for believing that such was really the case, and the difference is to be attributed to the type of gage used.

The instructions for setting these gages stated that they should be set remote from all obstacles, and distant from them by at least twice the height of the obstacle.

After 1833 a conical type of gage was used, the details of which are shown in the accompanying sketch.² Measurement of the rainfall was made by putting a graduated stick down into the gage. This stick was graduated so as to give a reading in hundredths of an inch for the first three-tenths of an inch, and thereafter by fifths of an inch. The instructions for the setting of these gages were the same as those for the older type, except that they were to be placed with their mouths 8 feet above the surface of the ground.

All of these old records indicate quite uniformly a lower value for the rainfall than do the results of more recent observations. While it is impossible to state absolutely the reasons for this apparent difference, it is probably due (1) to loss by evaporation from the first type of gage used; (2) to the unapproved method of measuring the snowfall; (3) to the placing of the conical gage 8 feet above the ground; this gage would therefore probably register about 3 per cent less rain than the standard gages now in use.

¹ A report to C. E. Davis, department engineer, and J. Waldo Smith, chief engineer, Board of Water Supply, city of New York. Communicated by permission of the Board.

² Not reproduced here.—EDITOR.